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A Guide to Southern Pine Seed Sources

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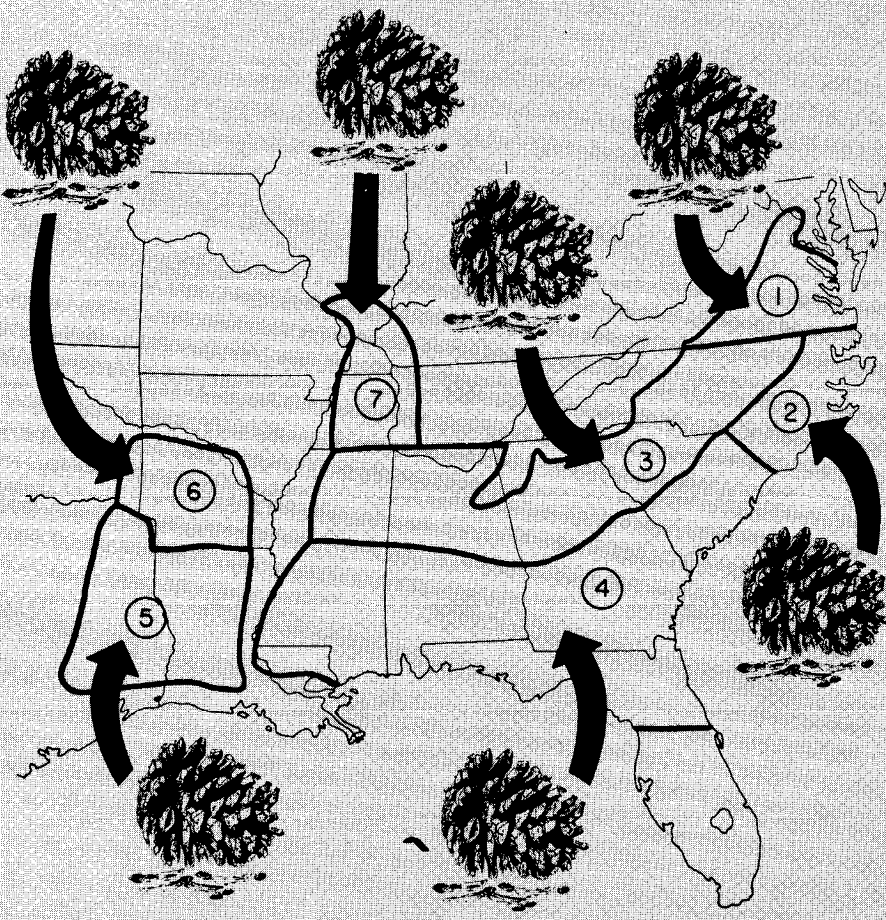

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The authors thank Ozzie 0. Wells of the Southern Forest Experiment Station for his many contributions to this publication. Ozzie was originally a coauthor but decided to retire in January 1986. He provided much of the text and many references for this'publication before his retirement.

The team of Philip C. Wakeley and Wells dominated the literature on geographic variation of the southern pines for many years. Together and separately, Wakeley and Wells made an outstanding contribution to southern forestry, They provided the basic foundation of geographic variation upon which all of the effective southern forest tree improvement programs have been built. Their well-written publications with effective summaries of large amounts of data have been instrumental in the increased productivity of southern forests.

After the death of Wakeley in 1983, Wells carried on this tradition of outstanding publications. All of us in southern forestry greatly appreciate the fine work of Phil Wakeley and Ozzie Wells.

Contents

A Guide to Southern Pine Seed Sources

ABSTRACT

The selection of an appropriate seed source is critical for successful southern pine plantations. Guides for selection of seed sources are presented for loblolly, slash, longleaf, Virginia, shortleaf, and sand pines. Separate recommendations are given for areas where fusiform-rust hazard is high.

KEYWORDS: Planting zones, provenance tests, geographic variation, *Pinus* *Pinus elliottii, Pinus* palustris, *Pinus virginiana, Pinus* ***echinata,*** *Pinus clausa.*

Introduction

Establishing a forest plantation is hard work, and it is expensive. Seedlings must be bought, and vegetation that may compete with the young trees should be controlled. The seedlings must be cared for before they are planted, and they must be placed in the ground carefully, one at a time. Finally, the plantation must be protected as it develops. The cost of the seedlings is only a small part of the total. Yet a poor choice of planting stock frequently reduces the productivity of plantations and sometimes causes outright failures.

Of course, the proper species must be chosen for the planting site. But the choices do not end there. Among southern pines, the most commonly planted species in the Southern United States, it is also important to use the best seed source. If you are planting in coastal South Carolina, are you better off with planting stock from local, Virginia, or Louisiana seeds? This publication is designed to help you make these critical choices.

Does the seed source make all that much difference? It certainly does. Many years of scientific study show that the seed source can strongly affect survival and subsequent growth of southern pines. Perhaps the most important early study of pine seed sources was Philip C. Wakeley's Bogalusa, LA, planting of 1927. There, loblolly pines (*Pinus taeda* L.) grown from local seeds produced about twice the wood volume through age 22 as did trees of the same species grown from Arkansas, Georgia, and Texas seeds. Since Wakeley's pioneering study, a great deal has been learned about geographic variation in southern pines. The Southwide Pine Seed Source Study was a cooperative effort initiated in 1961 by the Southern Forest Tree Improvement Committee,: Federal, State, university, and industry foresters throughout the South worked together to discover the patterns of geographic variation in the southern pines. The results of this work are summarized in publications by Dorman (1976), Wakeley (1961), Wells (1969, 1983), and Wells and Wakeley (1966).

These studies show that most southern pine species have reacted to differences in environmental conditions by developing different traits in different places through the process of natural selection. Therefore, there are races (ecotypes) of southern pines that grow faster in certain areas than in others. Some of these races are more resistant to disease or more tolerant of cold than other pines of the same species. The recognition of these patterns of geographic variation was the first step in the process of genetic improvement of the southern pines. All successful southern pine breeding programs are built on this foundation of geographic variation. Important gains in growth and disease resistance can often be made simply by selecting the best seed source for a given planting location. With some species, additional gains can be had by using the improved stock coming from tree breeding programs.

Planting seedlings from a seed source that is poorly adapted to your site can cause devastating losses. Even if the trees survive, their reduced growth will adversely affect yields throughout the timber rotation. It is better to postpone planting for a year rather than to risk the unfortunate results of planting ill-adapted seedlings.

Gene Conservation

Much has been written in recent years about conservation of gene pools in breeding programs. Forests in the South contain a rich gene pool that is not likely to be depleted by tree breeding. In fact, the moving of pollen and seeds great distances for breeding and planting encourages new genetic combinations that were previously unknown.

Tree improvement programs utilize genes and gene complexes that are only a small sample of the entire gene pool. These programs conserve genetic resources in clone banks, seed orchards, and genetic tests. In addition, these programs often create new genetic variability when trees from widely separated areas are intermated and their offspring are utilized for reforestation.

Substantial areas of southern forests are regenerated by natural methods. These areas will preserve much of the natural gene pool of the forest species of the South.

We recommend that all southern forestry organizations establish the following programs to encourage the preservation of the existing southern gene pool and to assure a wide genetic diversity for the future:

- Promote the use of genetically sound practices for both artificially and naturally regenerated forest stands.

- Discourage dysgenic practices such as high-grading and diameter-limit logging.

- Encourage land owners to:

  a. Leave only the highest quality seed trees when natural regeneration is used.

  b. Leave an adequate number of seed trees which will add to the diversity of the gene pool.

- Inform the public about the risks of planting poorly adapted seedlings or seeds.

- Continually evaluate the status of minor, threatened, and endangered forest species. Establish natural areas for the preservation of these species. Plant these species whenever suitable sites are available.

Select the Best Species for Your Site

When a site is to be regenerated, the choice of species is often the most critical decision to be made. If there are abundant, healthy, fast-growing trees on the site, probably the safe choice is to replant the same species. However, if there are no trees, or only a few trees which are slow-growing, poorly formed, and obviously not well suited to the site, another species or possibly another seed source of the same species should be considered. A common mistake is to use a single species over a large area without considering the variation in site quality within the area (Balmer and Williston 1974). The best indicator for a particular site is a healthy, vigorous plantation growing on a similar site. Good survival and growth through at least one-half of the rotation usually is a reliable predictor of success.

Other important considerations are the product desired, and nontimber considerations such as hunting or grazing, and local fire and disease hazards.

The following checklist may be helpful in choosing a species:

- Are there pines growing locally?
- Are these trees healthy and fast growing?
- What products are desired?
- Will the land be hunted or grazed?
- Are there local disease hazards such as fusiform rust?
- Is the land vulnerable to wildfire or arson?
- Is the land subject to flooding or extreme drought?
- Is the area likely to have ice storms?

Careful consideration of these questions should expedite the selection of the best species to plant. Additional information on species selection can be found in Balmer and Williston (1974) and Dorman (1976).

Physiographic Regions of the South

Conditions for tree growth vary greatly over the South due to differences in geology, elevation, soils, climate, and competing vegetation. Figure 1 shows the major physiographic regions of the South. Within these physiographic regions, southern pines have evolved into distinct species, races, and ecotypes.

Genetic Improvement of the Southern Pines

Seed orchards have been established to supply genetically improved seeds for certain physiographic provinces or geographic areas. For example, the Georgia Forestry Commission established the Arrowhead Seed Orchard from trees selected within natural stands and plantations growing on the coastal plain of Georgia. The seeds collected from this orchard are used to raise seedlings for planting on coastal plain sites in

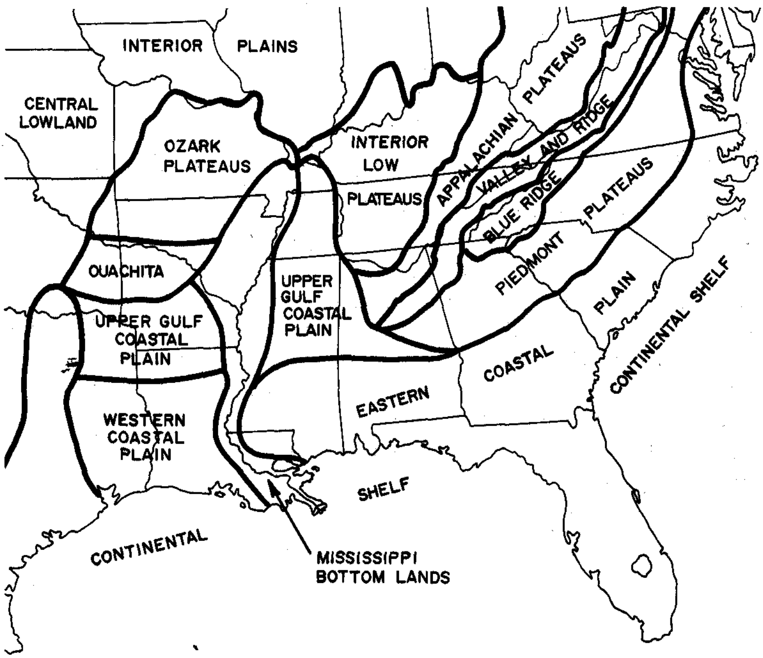

Figure l.-Physiographic provinces of the South.
(Adapted from Nelson and Zillgitt 1969.)

Georgia. These seedlings may not perform well on piedmont or mountain sites. Until the seedlings are actually tested on these other sites, it is impossible to predict how well they will survive and grow there. For this reason, it is important to carefully match all seed sources with the planting site. A genetically improved seedling is of no value if it dies or will not grow because it is not adapted to the planting site.

A tree is selected for seed orchard use on the basis of its performance in competition with its neighbors on a specific site for a specific period of time. Although the majority of these sites are coastal plain sites, some may not be "typical" coastal plain sites. If a sufficiently large number of trees is used to establish the orchard, a fair amount of site variation is sampled in the selection process. As a result, natural cross pollination within the orchard will create many new genotypes that should be adapted to a wide range of sites.

Progeny tests are designed to estimate the breeding value of the selected trees. When the progeny of certain selections do not perform well on the test sites, the grafts of those selections will be rogued (removed) from the orchard. If the test sites are a good representation of regeneration sites, the progeny test will weed out most of the poorly adapted families.

When the progeny of a select tree perform well on one site but poorly on another site, compared with other seedlings, there is a genotype x environment interaction. Since these genotype x environment interactions have usually been small in most southern pine progeny tests, it appears that first-generation seed orchards are producing trees with a wide range of adaptability.

Movement of Seed-Orchard Seeds and Seedlings

Moving seeds or seedlings to a region where they have not been tested involves some degree of risk. This is true for seedlings from seed orchard seeds as well as from woods-run seeds. Drought, ice, or extreme cold can be devastating to trees from seed lots that are not adapted to that specific hazard. The decision to plant fast-growing seedlings, which may not be adapted to local hazards, should be based on a comparison of the potential gain in wood production with the risk of loss from extreme weather, pathogens, or unusual growing conditions.

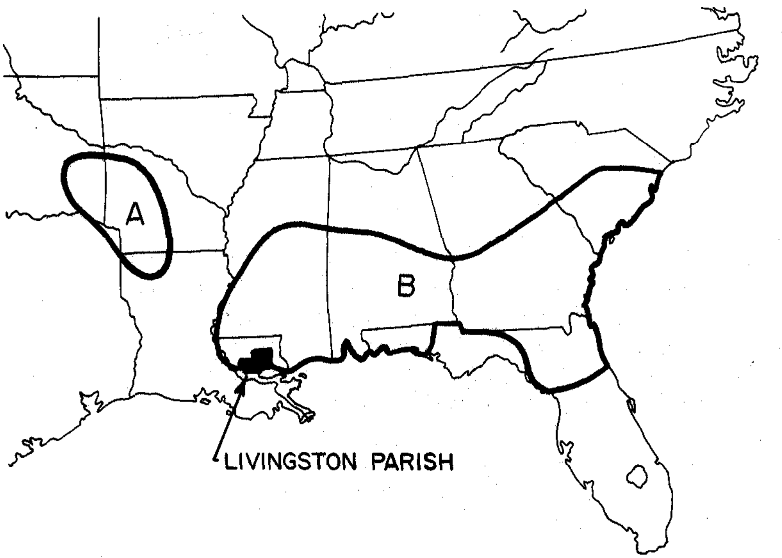

Figure Z.-Areas of major commercial use of nonlocal loblolly pine seedlings (Kraus and others 1984). Coastal North Carolina seeds used in Arkansas + Oklahoma (A) for increased growth rate. Livingston Parish, Louisiana, seeds used from Mississippi to South Carolina (B) for increased rust resistance.

Some organizations have elected to accept some risk in the belief that the additional wood produced by fast-growing sources will outweigh the possible loss. Weyerhaeuser's planting of North Carolina coastal loblolly seed orchard seedlings in Oklahoma and Arkansas has been very successful for several years (Lambeth and others 1984) (fig. 2). Seed source studies have also indicated a 10- to l&-foot height advantage of South Carolina coastal loblolly seedlings over an Oklahoma source after 25 years in a south Arkansas plantation (Wells and Lambeth 1988). Similar gains have been reported with other Atlantic coastal loblolly sources (Lantz and Hofmann 1969; Wells and Switzer 19'71). Likewise Livingston Parish loblolly seedlings have been planted over hundreds of thousands of acres in the southern coastal plain (fig. 2). They have exhibited substantial rust resistance while maintaining good growth rates (Wells 1985).

The decision to plant seeds or seedlings which are not native to a *given* area always involves some degree of risk. Even long-standing exotic plantation programs encounter new hazards; for example, *Dothistroma* needle blight in *Pinus radiata* plantings in Brazil, South Africa, and New Zealand (Zobel and Talbert 1984). However, new pathogens or disastrous weather patterns can also affect native stands. Witness the growing concern over pitch canker in the South or the frequent hurricane damage on the coast of the Gulf of Mexico.

State *Forestry* Organizations

Because of their diverse clientele, State forestry organizations must take a more conservative approach to seed sources than forest industry. Few nonindustrial private forest landowners have the knowledge to make sound decisions about the best sources to plant on their own land. Indeed, far too few service foresters are in a position to offer well-founded advice on this question. For this reason, most State nursery programs provide seedlings from local sources. Recently, however, a number of Southern States have grown loblolly seedlings from Livingston Parish, Louisiana, seed because of their good fusiform-rust resistance and fast growth.

Seedlings from Southern State seed orchards can be expected to have significantly improved bole straightness and branching characteristics, with moderately improved growth rates. Seedlings from rust-resistant seed orchards should have greater resistance to fusiform rust than nursery-run seedlings with no reduction in growth rates or wood quality.

Fusiform Rust

In areas of high rust hazard, landowners and foresters often must choose between unimproved seedlings with some natural resistance to fusiform rust and susceptible but faster growing seed-orchard seedlings. First-generation seed orchards are now producing enough seeds to satisfy most planting requirements throughout the South, but the rust-resistant orchards are several years from fulfilling demand. The decision to use seedlings from rust-susceptible orchard seeds that have been genetically improved for growth rate and form or to use seedlings from unimproved but resistant wild seeds (e.g., Livingston Parish or east Texas loblolly) is difficult. Ideally, it should be made by integrating several factors: degree of improvement in traits other than resistance expected from orchard seeds, degree of improvement expected in resistance from wild seeds, and the hazard rating of the area to be planted. Research aimed at quantifying this decision is now underway. A growth and yield model incorporating fusiform rust will be used in this effort (Nance and others 1983).

Seed and Seedling Certification

Certification programs are designed to identify and control the quality of forest tree seeds and seedlings (Barber 1975). With the exceptions of Oklahoma, Tennessee, and Virginia, all the Southern States in which loblolly pine is a major species have laws to certify forest tree seeds. Under these laws, certification can be obtained for seeds originating in natural stands, seed production areas, or seed orchards. In some cases, the expected amount of improvement in growth and disease resistance from seed-orchard seeds is included in the certification.

Certified seeds must also meet established standards of purity, percentage of filled seed, and germination. These requirements protect the buyer and encourage the seller to offer only seeds of known origin and quality.

In most States, three levels of seed certification are available:

1. Source-Identified Seeds (Yellow Tag). These seeds may be from natural stands, plantations of known provenance, or seed production areas of known geographic origin. Only the geographic location is certified.

2. Selected Tree Seeds (Green Tag). Selected tree seeds are from untested but rigidly selected trees or stands that have potential, but not proof, of genetic superiority.

3. Certified Tree Seeds (Blue Tag). These are seeds from trees of proven genetic superiority, produced so as to assure genetic identity. At present, these seeds are usually from seed orchards in which the selected trees have been progeny tested and the poorest trees removed on the basis of the test results.

The international certification of forest reproductive material is governed by the Organization for Economic Cooperation and Development (OECD) (Rudolf 1974).

Southern Pines

Species

This section provides specific information on seed sources for the southern pine species that are commonly used in forest plantations: loblolly, slash (*Pinus elliottii* Engelm.), longleaf (*P. palustris* Mill.), Virginia (*P. virginiana* Mill.), shortleaf (*P. echinata* Mill.), and sand pines (*P. clausa* (Chapm. ex Engelm.)) Vasey ex Sarg. Additional information on pitch pine (P. *rigida* Mill.), pond pine (P. *serotina* Michx.), spruce pine (*P. glabra* Walt.), and Table Mountain pine (*P. pungens* Lamb.) can be found in Dorman (1976).

Southern pine species vary widely in natural range, economic value, and degree of genetic improvement. In this section, we describe the natural range, geographic variation, genetic improvement, and recommended planting zones for the species mentioned.

It must be emphasized that local site conditions such as soils, slope, and competing vegetation must be carefully considered in any site analysis. These planting zone recommendations are baaed on the majority of sites within the zone, but local exceptions will occur.

Literature citations indicate sources of more detailed information.

Hybrids

The southern pine species often hybridize in areas where different species occupy the same sites. The most common natural hybrids are Sonderregger pine (longleaf x loblolly) (Chapman 1922), loblolly x shortleaf pine (Zobel 1953), and loblolly x pond pine (Saylor and Kang 1973).

The pitch x loblolly pine hybrid has been produced artificially in Korea for many years (Hyun 1970) and is currently planted on cold, dry sites on the Cumberland Plateau (Little and Trew 1976).

Recent work in the South has indicated that shortleaf x slash pine hybrids often outgrow the parental species (Wells and others 1978). Research with loblolly x shortleaf pine hybrids indicates the potential for improved fusiform-rust resistance, when compared with the parental species (La Farge and Kraus 1930).

The successful planting of hybrids requires a very careful site analysis. Both the pitch x loblolly hybrid and the shortleaf x loblolly hybrid will perform well when the planting sites are properly selected. Additional information on southern pine hybrids may be found in Dorman (1976).

Loblolly Pine

Loblolly pine is the most important southern pine. It produces over half of the total southern pine wood volume (Dorman 1976), and it accounts for about 80 percent of all southern pine seedling production in the United States. Because of loblolly pine's importance, its breeding and planting programs are the largest in the world.

Within its natural range, which extends from southern New Jersey to southeast Texas (fig. 3), loblolly pine occupies a great diversity of sites. It grows faster than any of the other southern pines on well-drained productive sites. It is not the best choice, however, on very dry sands or on wet flatwoods sites.

Geographic Variation

Geographic variation in loblolly pine has been well documented for growth rate, disease resistance, cold tolerance, and drought resistance (Dorman 1976). Eastern coastal sources are usually faster growing and more susceptible to fusiform rust than are western sources. On the other hand, loblolly sources from west of the Mississippi River are usually more drought resistant than eastern sources (Wells 1985).

Loblolly seedlings from Livingston Parish, Louisiana, have been widely planted on coastal plain sites throughout the South due to their fast growth and good resistance to fusiform rust. Because they are highly

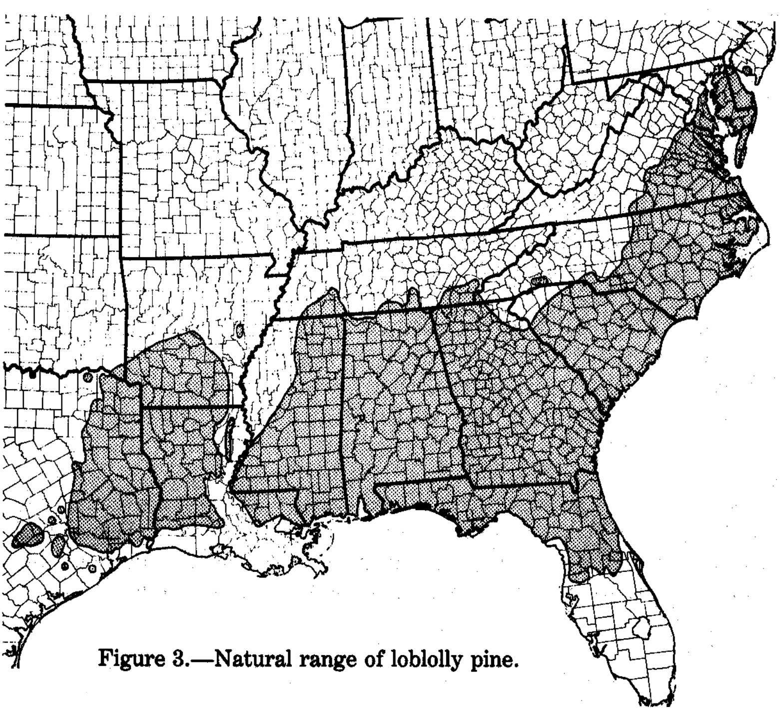

Figure 3.—Natural range of loblolly pine.

susceptible to ice damage, however, these seedlings should not be planted too far north. (See discussion under Fusiform Rust.)

Genetic *Improvement*

Genetic improvement of loblolly pine started in the mid-1960's with the establishment of seed production.areas and seed orchards. Seed production areas were high-quality natural stands thinned to the best 10 to 20 trees per acre and managed for cone production. Although the genetic gain calculated from seed production areas was small (Easley 1963), they were convenient sources of seeds from above-average trees in known geographic areas.

Seed orchards of loblolly pine were established primarily by grafting. The parent trees were selected for fast growth, good form, high-quality wood, and freedom from insect and disease symptoms. Progeny tests indicate a gain of from 10 to 20 percent in volume and up to 32 percent in value for first-generation progeny compared with unimproved nursery-run seedlings (Talbert and others 1985).

Some loblolly pine seeds from first-generation seed orchards are currently available on the open market.

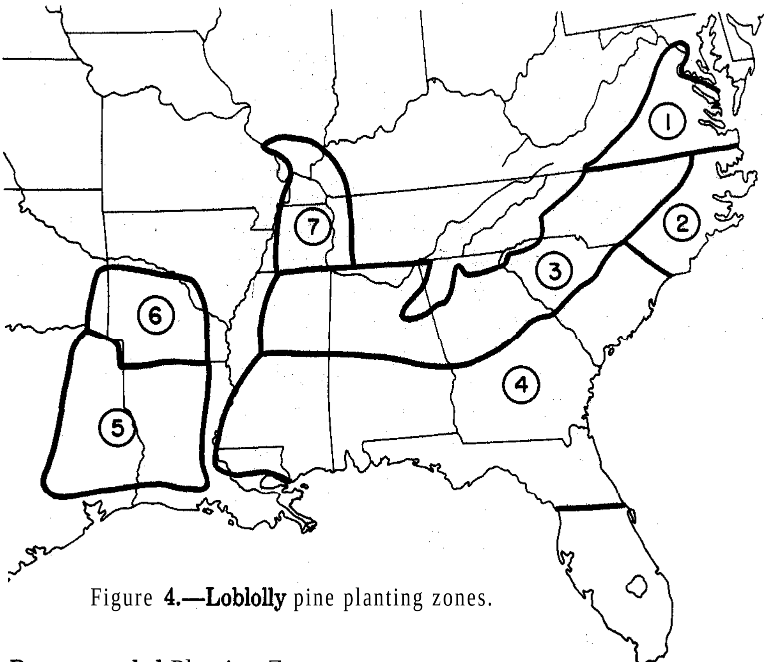

Figure 4.—Loblolly pine planting zones.

Recommended Planting Zones

Loblolly pine planting zones have been located in the South based on topography, climate, soils, vegetation, and (of greatest importance) plantation performance. These planting zones are shown in figure 4. The recommended seed sources for each zone are presented on the pages that follow. Recommendations are summarized in table 1.

Zone l-Virginia. If seeds from a local seed orchard or seed production area are not available, seeds should be collected from local stands with above-average stem form and growth. Where seeds from a local stand are not available, movement of seeds a short distance to the north would probably be more advantageous than moving seeds south. For example, seeds from southern Virginia would probably perform well in Maryland and Delaware, but these seeds would not be a good choice for North Carolina. When local seeds are not available, the most conservative approach would be to use seeds from the North Carolina coastal plain in the coastal plain of Virginia. Likewise, North Carolina piedmont seed should be used in the piedmont of Virginia.

Zone 2—Coastal Plain: North Carolina. In the coastal plain of North Carolina (fig. 4, zone 2), local seed sources should be favored. These coastal sources from the Carolinas have been consistently fast growing in tests on a wide range of sites in the South (Lantz and Hofmann 1969; Wells and Switzer 1971). There may be some slight growth advantage to moving seeds north from South Carolina into North Carolina. However, due to the generally colder climate in the piedmont of these States, and the increased frequency of ice and snow, it is not recommended that coastal plain sources of loblolly pine be moved into the piedmont (Jones and Wells 1969). Northern piedmont sources of loblolly have grown well, however, for up to 8 years in the northern coastal plain (Talbert and Weir 1979).

Zone “Piedmont: North Carolina to North Mississippi. The northern portions of Mississippi, Alabama, and Georgia and the piedmont areas of South Carolina and North Carolina (fig. 4, zone 3) make up another area of relatively uniform climate. In the absence of improved local sources of loblolly pine, movement of seeds either east or west within this region should produce acceptable results.

Zone 4—Coastal Plain: South Carolina to Mississippi. The area extending from Louisiana east of the Mississippi River through the coastal plain of Mississippi, Alabama, north Florida, Georgia, and South Carolina is climatically homogeneous (fig. 4, zone 4). Fusiform rust is most prevalent in this area, and in some local “hot spots” almost totally destructive. If seeds or seedlings of improved strains of loblolly pine with proven disease resistance are not available, the best natural seed source for this area is Livingston Parish, Louisiana. East Texas loblolly has also been used successfully on high-rust-hazard sites, but this source is usually slower growing than Livingston Parish loblolly. (See Specific Problems - Fusiform Rust.)

Zone S-East Texas to West Louisiana. West of the Mississippi River, in Louisiana and southeast Texas (fig. 4, zone 5), local seed sources have grown well. They are consistently more drought hardy than sources from east of the river and survive well after planting. Eastern sources of loblolly have suffered heavy mortality when planted in this zone (Long 1980).

Zone 6—South Arkansas to Southeast Oklahoma. Several long-term tests have shown that loblolly pine from east of the Mississippi River has, inherently, a faster growth rate than western loblolly. Trees from some eastern sources have grown about 8 feet taller than western trees in 26 years-a substantial difference (Wells and Lambeth 1999). In the last few years some forest products manufacturers with land in southern Arkansas, southeastern Oklahoma, and the Ouachita Mountains of Arkansas and Oklahoma have planted substantial numbers of loblolly seedlings from Atlantic Coastal Plain sources (Lambeth and others 1984).

Such seed source movement entails a certain amount of risk; just how much is not certain. In the long-term tests mentioned above, certain eastern sources suffered heavy mortality at about age 20. Damage was greatest among sources from the mildest climates; i.e., near the gulf and Atlantic coasts in Florida, but a few other sources, distributed at random east of the Mississippi River, were also hard hit. Damage was thought to be due to very high stand densities in the fast-growing coastal sources, in conjunction with bark beetle attack (Wells and Lambeth 1983). Local Arkansas and Oklahoma sources were not damaged. It is hoped that Atlantic coast sources of loblolly can be successfully grown in Arkansas and Oklahoma if they are restricted to the better sites and if stands are kept thrifty by judicious thinning.

All factors considered, the use of loblolly from the Atlantic Coastal Plain is probably not a viable strategy for most small private landowners west of the Mississippi River. It requires the ability to carefully assess the geographic location and site quality, the resources and long-term continuity to carry out thinnings when necessary, and the capacity to absorb losses. Also, small private landowners would have to make special arrangements to obtain seeds and to produce seedlings. The State nurseries in Arkansas, Oklahoma, Louisiana, and Texas produce only seedlings of local origin. Therefore, only large forest-products industries have the facilities to take advantage of this technology at present.

Zone 7—Western Tennessee, Western Kentucky, Southern Illinois. Western Kentucky and western Tennessee often experience severe cold. Loblolly is not native to this area, but Barbour (1980) has done extensive testing of loblolly seed sources in this area. Loblolly seeds from northern Mississippi, northern Alabama, and northwestern Georgia have performed much better than other sources. Sources from eastern Virginia, northern North Carolina, and central Arkansas have also performed well.

In southern Illinois, Gilmore (1980) found loblolly from southwestern Arkansas and Maryland to be the only sources tested which were resistant to cold and ice damage.

Table **1.—Recommended loblolly** seed sources for **each** planting **zone**

Zone	Preferred seed sources	Special situations
1-Virginia	1. Local seed orchard or **seed-production** area 2. **High-quality** natural stands or **plantations** in Zone 1 3. Northern North Carolina	Eastern Shore: 1. Local seed **orchards** 2. Improved sources from Virginia coastal plain or piedmont
2—Coastal Plain: North Carolina	1. Local **seed** orchard or seed-production area 2. **High-quality** natural **stands** or **plantations in the southern part of Zone 2**	— —
3-Piedmont: North Carolina to north Mississippi	1. **Local seed** orchard or seed-production **area** 2. **High-quality** natural stands or **plantations in Zone 3** 3. **High-quality** sourees from Vii or **Maryland**	— — —

4—Coastal Plain: South Carolina to Mississippi	1. Improved sources with proven **fusiform-**rust resistance	Sandhills sites: Careful site analysis required. Longleaf, Choctawhatchee sand pine, or Texas drought-hardy loblolly may be suitable
	2. Livingston Parish (see **Fusiform** Rust section)	**High fusiform-rust-hazard** sites: Use **fusiform-rust-resistant** seed orchard or Livingston Parish (see Fusiform Rust section)
5—East Texas to west Louisiana . . . . ..*..*......*......	1. East Texas sources	Dry sites: drought-hardy source from Texas Forest Service
6—South Arkansas to southeast oklahoma	Atlantic coastal sources **from** Zone 2 have produced good growth on the better sites on short rotations, but the risk of loss is substantial (see discussion under Zone 6)	Dry sites: Local seed orchards or seed-production areas. Shortleaf should be planted on dry ridge sites or at higher elevations
O-Western Tennessee, western Kentucky, southern Illinois	1. North Mississippi, north Alabama, or northwest **Georgia**	—
	2. Central Arkansas	—
	3. Eastern **Virginia,** northeastern North Carolina, or the eastern shore of **Virginia** and Maryland	—

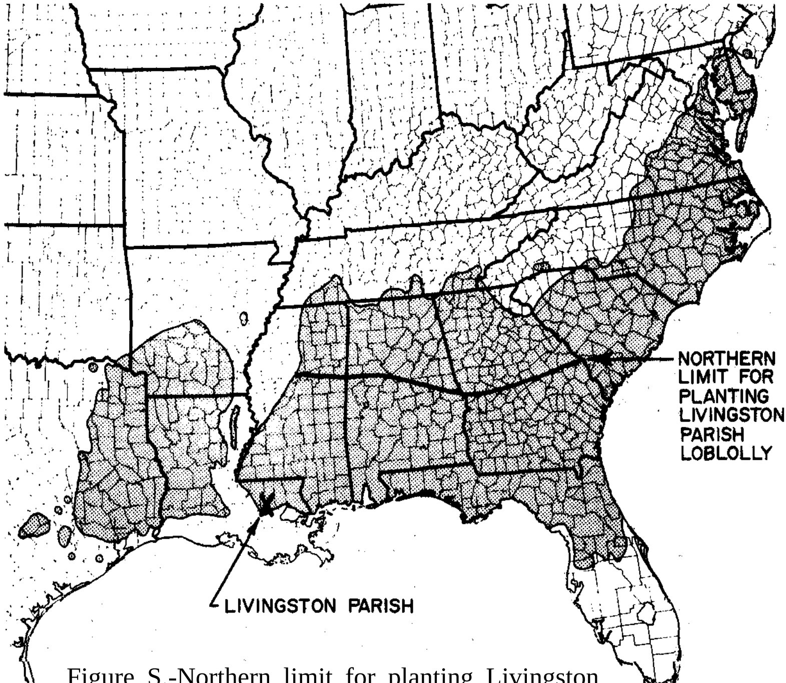

Figure S.-Northern limit for planting Livingston Parish loblolly pine.

Specific Problems

Fusiform Rust. Most loblolly pine sources from west of the Mississippi River and from the northeastern extremity of the range (Maryland and Virginia) are classed as strongly resistant to fusiform rust. Livingston Parish, Louisiana, and east Texas sources are moderately resistant, and all the rest of the loblolly population east of the Mississippi River is susceptible. Most western sources are slower growing than sources from the same latitude east of the Mississippi River, however, and the northeastern sources are relatively slow growing when brought south to areas of high rust hazard.

Livingston Parish is the only geographic source with high rust resistance that grows as fast as the generally susceptible loblolly populations from the gulf and Atlantic coasts. It is sensitive to cold, however, and should not be moved north farther than the limits shown in figure 5. Livingston Parish seedlings have exhibited poor form north of this line in both Georgia (Wells 1985) and Arkansas (Wells and Lambeth 1983).

For planting sites with a high rust hazard, loblolly seed sources should be considered in the following order:

1. Seeds from a seed orchard established specifically for resistance to rust.

2. Seeds from a progeny-tested and rogued seed orchard in which the tests included a high-rust-hazard site.

3. Seeds from a progeny-tested seed orchard in which the tests included a high-rust-hazard site.

4. Unimproved seeds from Livingston Parish or east Texas.

5. Untested seed-orchard seeds.

6. Local woods-run seeds.

Dry Sites. Sandhills sites are a real challenge for reforestation. Often the key to success is the correct analysis of the site followed by the correct choice of species and seed source. Among the choices are longleaf pine (Dennington and Farrar 1983), Choctawhatchee sand pine (Outcalt and Brendemuehl 1985), and drought-hardy loblolly pine from Texas.

Carolina sandhills sites have traditionally been planted with either slash or longleaf pine. The slash pines usually grew very slowly, whereas the longleaf pines failed to survive. Recent studies by members of the N.C. State University-Industry Cooperative Tree Improvement Program (1983) have indicated that drought-hardy loblolly seedlings from Texas can survive and grow better than other loblolly sources and other species (including Choctawhatchee sand pine) on some sandhills sites. Although no source grew rapidly, the drought-hardy loblolly had high survival, very low rust, and a much greater volume than any of the other sources. The drought-hardy Texas loblolly source was also the most resistant source to fusiform rust on several other sites. These plantings are only 4 and 9 years old, but their results are encouraging in that they do provide some new alternatives for regenerating sandhills sites.

Slash Pine

Slash pine has a relatively small natural range from coastal South Carolina west to eastern Louisiana (fig. 6). The typical variety (var. *elliottii*) exhibits very little geographic variation in commercial traits, but many active breeding and planting programs worldwide are based on trees selected from this variety.

South Florida slash pine (var. *densa*) differs from the typical variety in a number of characteristics, including a seedling grass stage. In central Florida where the two varieties overlap, many traits vary in a clinal pattern (Fisher 1983).

Geographic Variation

Although major differences between slash pine populations are difficult to detect, Squillace (1966) has identified a definite geographic pattern of

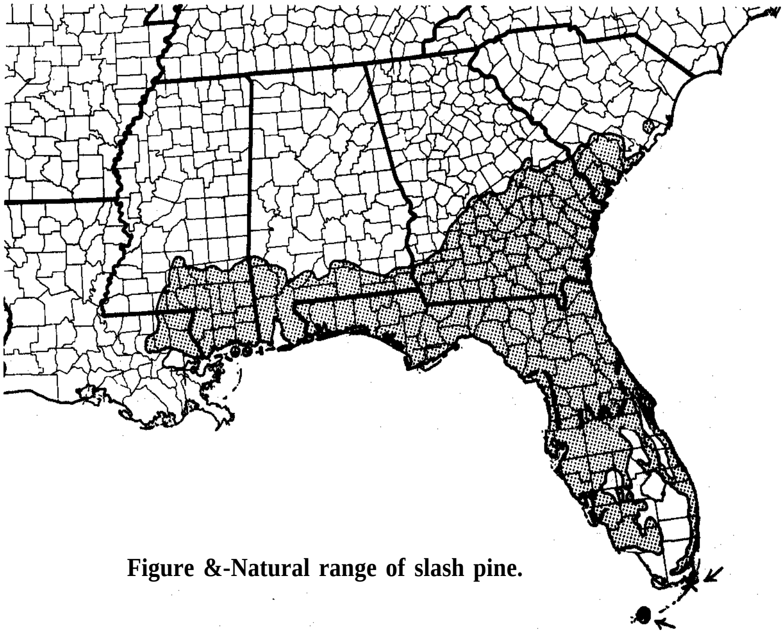

Figure &-Natural range of slash pine.

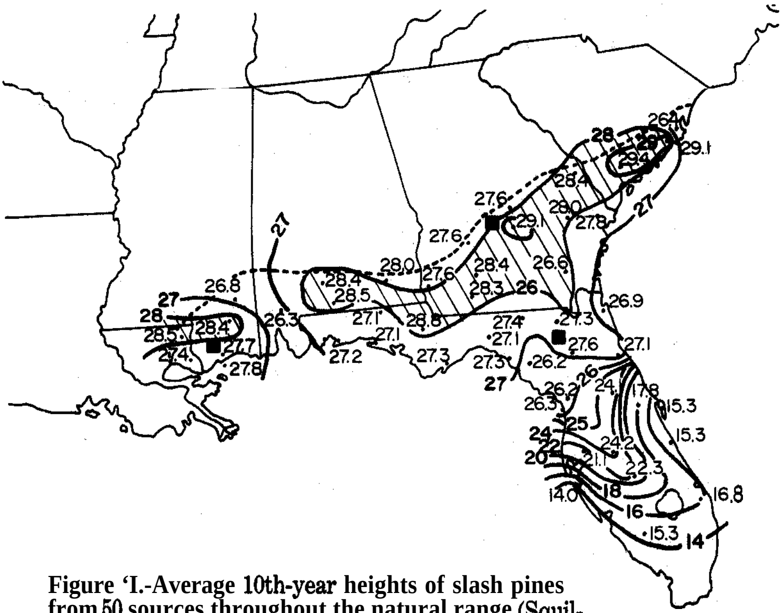

Figure ‘I.-Average 10th-year heights of slash pines from 50 sources throughout the natural range (Squillace 1966).

height growth at age 10. The best sources were from a narrow zone running from coastal South Carolina to southeastern Louisiana (fig. 7).

Unfortunately, no clear geographic pattern of fusiform-rust resistance has been identified within the natural range of slash pine (Goddard and others 1983).

Genetic Improvement

Slash pine seeds from tit-generation seed orchards are available on the open market. Although important effects of slash pine seed sources have seldom been recorded, some clones have demonstrated genotype × environment interactions (Rockwood 19'74). For this reason a local seed orchard is a safer source than a more distant orchard.

In addition to improved growth rate, the primary regeneration need is for improved resistance to fusiform rust. Seedlings from first-generation slash pine seed orchards have demonstrated good gains in growth, but fusiform-rust infection rates have been higher than expected (Kraus and La Farge 1984). Although 80 percent of the early slash pine selections in the Florida cooperative program produced progenies with above-average growth rates, 55 percent were below average in rust resistance (Goddard and others 19'73). Apparently, the early selection for rust resistance was not effective.

Recommended Planting Zones

The most important seed source recommendation for slash pine is to avoid the South Florida variety. The typical variety has performed better wherever planted. The most important commercial seed source of slash pine--southern Georgia and northern Florida-does have some of the characteristics of the South Florida variety to a small degree. It is less drought hardy and less cold resistant than slash pine from the northern or western extremities of the range (South Carolina, Mississippi, and Alabama). These characteristics are of little importance if the plantings are to be made within the natural range of slash pine where drought and cold do not reach critical levels, but it could be important if plantings are north or west of the natural range.

Although seed-orchard seeds are available, some woods-run seeds may still be collected and marketed. The following guidelines for source selection are suggested for either seed-orchard or unimproved seeds (Goddard 1983) for:

- Planting north or west of the species' natural range, seeds from the northeastern or western extremities of the species' range (South Carolina, Mississippi, or Louisiana) are preferred.

- Planting within the natural range of slash pine as far south as the latitude of Tampa, seeds from the optimum growth zone (fig. 7) should perform best.

- Planting south of the latitude of Tampa, seeds should be collected from near the latitude of Alachua County in northern Florida (Dorman 19'76). A high incidence of pitch canker has been observed when more northern seed sources were planted in southern Florida.

Because geographic variation occurs within as well as between varieties, seed buyers should demand certification of the exact origin (State and county) of seed lots.

Specific Problems

Fusiform Rust. When regenerating sites with a high fusiform-rust hazard, the following order of preference should be observed in selecting seeds and seedlings.

1. Seed orchards established specifically for increased rust resistance.
2. Seed production areas established in highly infected stands where selection of disease-free trees was intensive.
3. Seed-orchard cone collections restricted to the most rust-resistant clones in the orchard.

Pitch Canker. Natural stands in areas with a high incidence of pitch canker have experienced strong selection pressure against susceptible trees. Seed collection from the best trees in these local natural stands appears, therefore, to be the best procedure for obtaining stock with some resistance to the disease (Goddard and others 1983). Another alternative is to collect seeds from the most resistant clones in established seed orchards (McRae and others 1986).

High Gum Yield. When high gum yield is a primary objective, seedlings can be obtained from State seed orchards established for high gum yield. Most of these orchards were established with plant material from the USDA Forest Service naval stores breeding program at Olustee, FL. These seedlings should produce about 50 percent higher gum yields than nursery-run seedlings, with some improvement in growth rate and yield of tall oil.

Longleaf Pine

Longleaf pine is adapted primarily to coastal plain sites from southeastern Virginia to east Texas (fig. 8). The delayed height growth (grass stage) of this species is unique. It must be grown at low density in the nursery and it requires special care in storage, transportation, and planting.

Longleaf planting programs are currently being expanded in a number of organizations because the species has natural resistance to fusiform rust, excellent form, and high-quality wood.

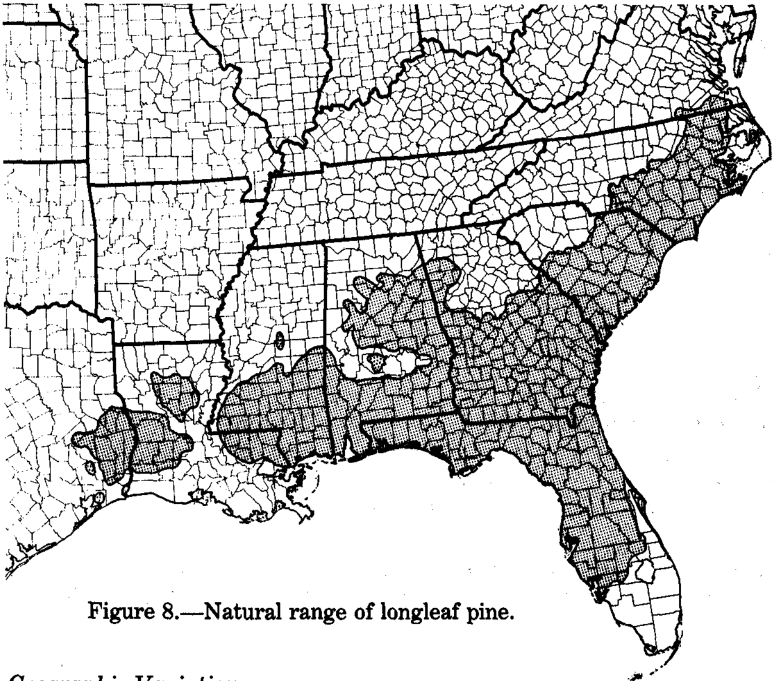

Figure 8.—Natural range of longleaf pine.

Geographic Variation

Geographic variation in longleaf pine is not as obvious as in loblolly and slash pine, but differences of commercial importance have been noted. It is most important, as in slash pine, to avoid seed sources from the southern extremity of the range. Seedlings from central Florida sources have a poor survival rate when planted north of peninsular Florida (Wells and Wakeley 1970a).

Longleaf from west of the Mississippi River should not be moved east of the river. Several tests have shown it to be more susceptible to brown-spot needle blight (*Scirrhia acicola*) than longleaf from the gulf coast east of the Mississippi River (Henry and Wells 1967).

Longleaf from the mountains of Alabama and Georgia should not be used near the gulf coast, nor should gulf coast stock be planted in the mountains. Growth losses will occur.

The central gulf coast seed source, from south Mississippi to about Okaloosa County, Florida, has grown exceptionally well in Southwide Pine Seed Source Study plantings 150 miles north and as far east and west as central Georgia and central Louisiana. Seedlings from this source also performed well in independent tests by the University of Florida-Industry Tree Improvement Cooperative. However, in a large and well-designed Southeastern Forest Experiment Station test—primarily of Georgia and Florida sources-the central gulf coast source did not perform best in Georgia. Georgia coastal plain sources were best in that test.

Sources from Georgia piedmont and the southern edge of the range produced the least volume per tree at 16 years.[1]

Farther north, longleaf seeds from North and South Carolina can probably be freely interchanged, and tests have shown no differences between sandhills and coastal plain sources. As in most species, seed collections from scattered trees at the northern extremity of the range (near the Virginia-North Carolina border) should be avoided. Seeds collected from large, continuous populations would be a better choice for most planting sites.

Genetic *Improvement*

Although there are 443 acres of first-generation longleaf pine seed orchards established in the South (Dennington and Farrar 1983), no improved seeds are currently available for sale, Primary emphasis has been placed on breeding for fast initial height growth (a shorter grass stage) and resistance to brown-spot needle blight.

Some seeds from seed-production areas may be available. The recommended zones should be observed with seeds from either wild stands or seed-production areas.

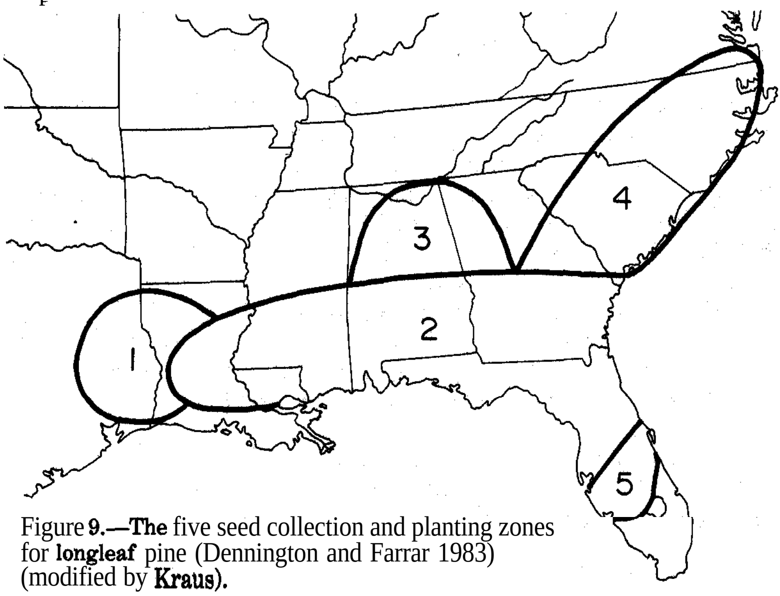

Figure 9.—The five seed collection and planting zones for longleaf pine (Dennington and Farrar 1983) (modified by Kraus).

Recommended Planting Zones

Within each of the five seed collection and planting zones (fig. 9), local sources have performed best (Dennington and Farrar 1983). In general, therefore, moving seeds from one zone to another is not recommended.

[1] Unpublished records, Southeastern Forest Experiment Station, Macon, GA.

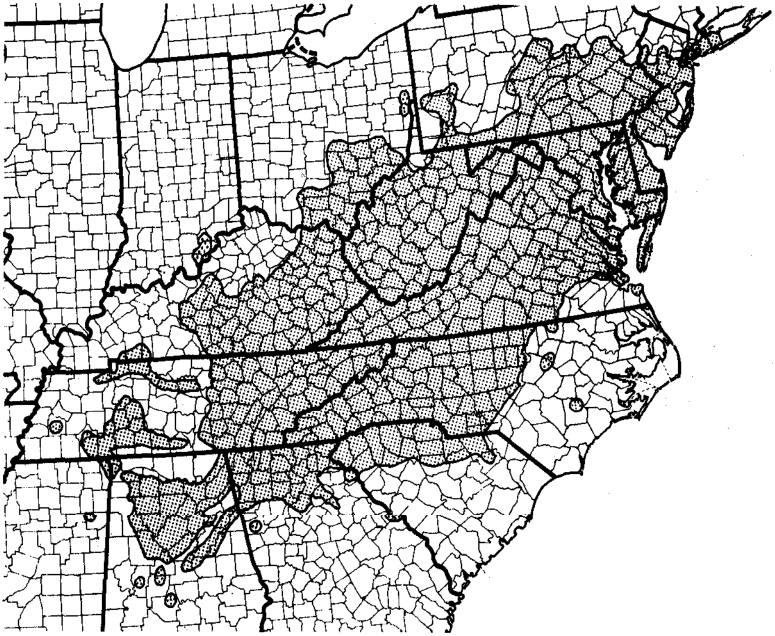

Figure lO.-Natural range of Virginia pine.

Virginia Pine

Virginia pine occupies a wide range from New York south to Alabama and Mississippi (fig. 10). It is widely planted for pulpwood and Christmas trees both within and south and west of its natural range.

Geographic Variation

Although differences have been recorded between Virginia pine populations in the Talladega Mountains of central Alabama and the sandhills of the mid-Atlantic States, there are insufficient data to declare these as distinct ecotypes (Kellison and Zobel 1974).

In a range-wide provenance study of Virginia pine, Genys (1966) found that sources from Alabama, South Carolina, Tennessee, and Virginia had high mortality when planted in Pennsylvania and variable performance when planted in Maryland and Tennessee.

In a lo-year-old study in Tennessee, the best sources of Virginia pine for Tennessee planting were from the central part of the great valley of Tennessee (Todd and Thor 1979).

Genetic Improvement

A number of seed orchards of Virginia pine have been established by Federal, State, and industrial organizations in the South. Due to the early flowering and heavy cone production of the species, these orchards have been producing commercial quantities of seeds for several years.

Due to the high interest in Christmas trees, cone collections in some orchards have been confined to production of Virginia pine trees with the best form and color for this purpose. Seeds and seedlings from the Kimberly-Clark seed orchard have been in great demand in recent years by Christmas tree growers. Trees from this central Alabama source have exceptionally good form and good growth rates.

Recommended Planting Zones

In the absence of definitive seed zones, local seeds should be used whenever possible. If local seeds are not available, it is safer to move seeds east or west within the same province rather than north or south.

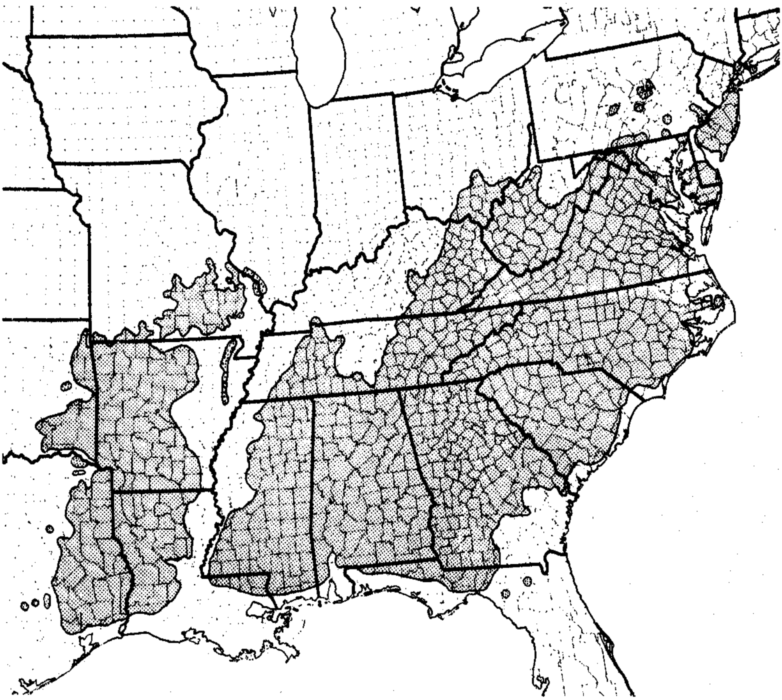

Figure Il.-Natural range of shortleaf pine.

Shortleaf Pine

Shortleaf pine has the most extensive natural range of any southern pine but produces only about one-half of the total southwide wood volume of loblolly pine (Dorman 19'76). The natural range of the species extends from New York to Oklahoma and Texas (fig. 11) over a very wide range of sites.

Geographic Variation

Geographic variation in survival and growth of shortleaf pine is related to the climate of the seed source (Wells 1979; Wells and Wakeley 19'70b). In plantations as far north as northern Mississippi, trees from southeastern sources (Georgia and South Carolina) survived betterand grew faster than trees from northern sources. In plantations in Pennsylvania and New Jersey, however, the northern sources were clearly superior to southern sources in both survival and growth.

Genetic Improvement

Clonal seed orchards of shortleaf pine have been established primarily by Southern State forestry organizations and the USDA Forest Service. A few forest industries have also established orchards. Currently there are 667 acres of shortleaf pine seed orchards (Kitchens 1987).

In recent years, the planting of shortleaf pine has decreased because loblolly pine survives better and grows faster on many sites formerly occupied by shortleaf (Lambeth and others 1984). It is encouraging to note, however, that on the Ouachita and Ozark National Forests the survival of shortleaf seedlings from the seed orchard was 22 percent higher than the survival of nursery-run seedlings (Kitchens 1987).

Currently, most of the shortleaf pine seedlings planted in the South are on National Forests in Arkansas, Georgia, Kentucky, and Tennessee. Of the average of 22,666 acres planted annually to shortleaf pine, 18,696 acres are on National Forests (Kitchens 1987).

Seeds from shortleaf pine seed orchards are available from a number of organizations. The same geographic restrictions should be applied with seed-orchard seeds as with wild seeds. Genetic improvement is of little value if the seeds are not well adapted to the planting site.

Recommended Planting Zones

Figure 12 divides the range of shortleaf pine into five geographic zones. Based on these zones, seed-collection recommendations are:

Planting in zone	Collect seeds in zone
1 or 2	1 or 5 northern half
3	2, 3, or north 1/2 of 5
4	4
5	6

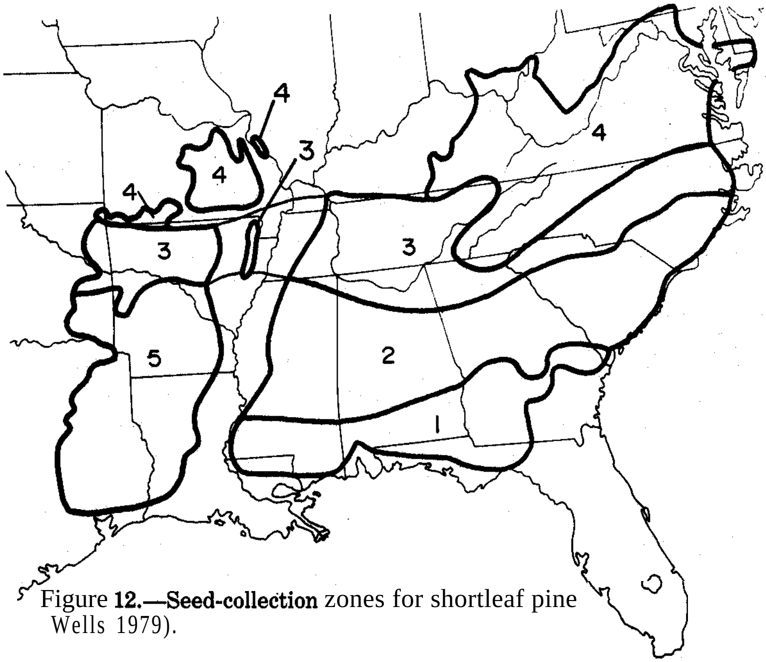

Figure 12.—Seed-collection zones for shortleaf pine
Wells 1979).

Specific Problems

Littleleaf Disease. In a seed source study of shortleaf pine planted on littleleaf sites in Georgia, South Carolina, and Virginia, Ruehle and Campbell (1971) found that upland sources had fewer disease symptoms than the coastal sources. The Prince Edward County, Virginia, source was the best overall source when all three plantations were considered. This source is in an area of high incidence of littleleaf disease, and the seeds may have been collected from resistant trees. In this case, natural selection would have favored those trees that were resistant to the disease. A similar procedure has been recommended by Goddard and others (1983) for improving the resistance of slash pine to pitch canker.

Sand Pine

The natural range of sand pine is restricted to deep sands in Florida and the southern tip of Alabama (fig. 13). The Ocala race (variety *clausa*) is found in the central part of peninsular Florida, while the Choctawhatchee race (variety *immuginata*) is located in the western end of the Florida panhandle and southern Alabama. The Ocala race has serotinous cones, whereas Choctawhatchee cones open normally.

Geogmphic Variation

In field tests of the two varieties, Choctawhatchee sand pine generally had higher planting survival, higher resistance to root rot, superior form, and greater tolerance to freezing temperatures (Burns 1973, 1975).

Genetic Improvement

Clonal seed orchards of Choctawhatchee sand pine have been established by several organizations in the South, primarily in Georgia and Florida. A seedling seed orchard of Ocala sand pine has been established by the USDA Forest Service on the Ocala National Forest (Lewis and others 1985).

Recommended Planting Zones

Choctawhatchee sand pine has been successfully planted on sandhills sites as far north as South Carolina (Hebb 1982). This race has performed better than any other pine species tested in the Georgia sandhills (Outcalt and Brendemuehl 1985). When they were last measured, the Georgia plantations ranged in age from 6 to 19 years, and there were no indications of serious damage from pathogens or weather. On the basis of this information, it should be safe to plant Choctawhatchee sand pine throughout the Georgia and South Carolina sandhills.

Planting of Ocala sand pine should be restricted to peninsular Florida, Direct seeding of Ocala sand pine has been successful on some sites on the Ocala National Forest, but the survival of planted seedlings has usually been poor.

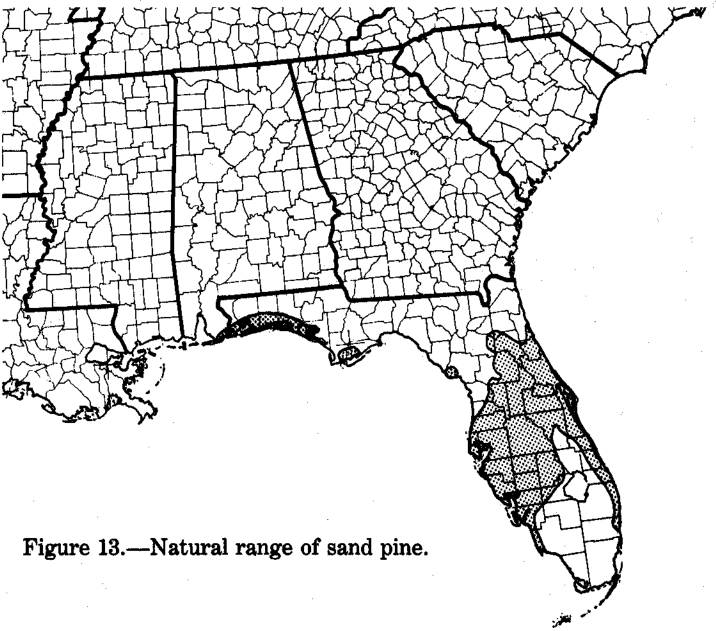

Figure 13.—Natural range of sand pine.

Glossary[2]

Adaptation. The process of evolutionary (genetic) adjustments fitting individuals or groups to their environment.

Cline. A geographical gradient of phenotype or genotype within the species' range. Determining whether a cline is genetic requires a teat in a single environment. Usually clinal variation results from an environmental gradient. Portions of populations exhibiting such continuous (clinal) change from one area to another should not be designated as ecotypes, races, or taxa.

Clone. A group of genetically identical plants derived asexually from a single individual.

Ecotype. A race adapted to the selective action of a particular environment. Most differences among ecotypes show up only when different ecotypes are tested in a uniform environment. Ecotypes are described, e.g., as climatic or edaphic.

Genotype. (1) An individual's hereditary constitution, with or without phenotypic expression of the one or more characters it underlies. Also the gene classification of this constitution expressed in a formula. The genotype is determined chiefly from performance of progeny and other relatives. It interacts with the environment to produce the phenotype. (2) Individual(s) characterized by a certain genic constitution.

Genotype-environment interaction. The failure of entries to maintain the same relative ranks and level of differences when tested in different environments.

Geographic race. The race native to a geographic area.

Geographic variation. The phenotypic differences among native trees growing in different portions of a species' range. If the differences are largely genetic rather than environmental, the variation is usually specified as racial, ecotypic, or clinal.

Local seed source. Source native to the locality in which the seedlings are to be grown, i.e., belonging to the indigenous geographic race. Its seed-collection zone is usually defined experimentally as being within a certain distance or elevation of the planting site.

Phenotype. The plant or character as we see it; state, description, or degree of expression of a character; the product of the interaction of the

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2 From Snyder, E.B. 1972. Glossary for forest tree improvement workers. rev. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 22 pp. Unnumbered public&ion.

genes of an organism (genotype) with the environment. When the total character expressions of an individual are considered, the phenotype describes the individual. Similar phenotypes do not necessarily breed alike.

Progeny test. Evaluation of parents by comparing the performance of their offspring. Accuracy is usually gained because several to many offspring per parent are evaluated under more controlled conditions than exist for the parent.

Race. A population that exists within a species and exhibits general genetic characteristics discontinuous and distinct from those of other populations. It is usually an interbreeding unit. When the distinguishing characteristics of a race are adaptive, the term is synonymous with ecotype, and the race is described similarly, e.g., climatic, edaphic.

Roguing. Systematic removal of individuals not desired for the perpetuation of a population; culling.

Seed-collection zone. Zone of trees with relatively uniform genetic **(racial)** composition as determined by progeny-testing various seed sources. The encompassed area usually has definite geographic bounds, climate, and growing conditions. A single geographic race may be divided into several zones.

Seed **orchard.** A plantation consisting of clones or seedlings from selected trees, isolated to reduce pollination from outside sources, rogued of undesirables, and cultured for early and abundant production of seeds.

Seed-production area. A plus stand that is generally upgraded and opened by removal of undesirable trees and then cultured for early and abundant seed production.

Seed **source. The** locality where a seed lot was collected; also the seed itself. If the stand from which collections were made was in turn from nonnative ancestors, the original seed source should also be recorded and designated as the ***provenance.***

Selection. Often synonymous with **artificial** selection, which is the choice by the breeder of individuals for propagation from a larger population. Artificial selection may be for one or more desired characteristics. It may be based on the tree itself (phenotypic), or on the tree's progeny or other relatives (genotypic). Refers also to the tree selected.

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The selection of an appropriate seed source is critical for successful southern pine plantations. Guides for selection of seed sources are presented for loblolly, slash, longleaf, Virginia, shortleaf, and sand pines. Separate recommendations are given for areas where fusiform-rust hazard is high.

KEYWORDS: Planting zones, provenance tests, geographic variation, *Pinus taeda, Pinus* elliottii, *Pinus* palustris, *Pinus virginiana, Pinus echinata, Pinus clausa.*

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